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FROM: W. C. Lee

SUBJECT: Advanced Life Support SMAP Mars Missions Solid Waste Model (Revision A)

The attached document covers the data used and procedures employed in revising the Mars missions solid waste model for fiscal year 2001 under STO ECAYS. The results of this revision are also tabulated in this document.

Please address any questions or issues regarding this report to Wen-Ching Lee (281-333-6826).

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ADVANCED LIFE SUPPORT
SYSTEMS MODELING AND ANALYSIS PROJECT

MARS MISSIONS SOLID WASTE MODEL (REVISION A)

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ADVANCED LIFE SUPPORT
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Prepared by

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Houston, Texas

Contract NSA9-19100

Prepared for

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

February 2001

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TABLE OF CONTENTS

Page

LIST OF TABLES

1.0 PURPOSE

The purpose of this memo is to document the data used and procedure employed in revising the solid waste model for Mars reference missions. This document is part of the effort of the solid waste trade study.

2.0 BACKGROUND

The most important data set for the trade study is the solid waste model. It is used as the design feed for all technologies to be evaluated in the trade study. The Waste Processing and Resource Recovery (WPRR) workshop document (Ref. 1) contains the original version of the solid waste model, as listed in Table 1.

The inedible plant biomass and the packaging material rates of Table 1 were critiqued and challenged by the Systems Modeling and Analysis Project (SMAP) community. Comments from the SMAP community included: 1) The inedible plant biomass was assumed as dry basis, which does not reflect the real situation, 2) The moisture content should be included in the inedible biomass, 3) The rate for packaging material seemed high and required verification, 4) The packaging material should be derived from the packaged food requirement, 5) The dry wastes and wet wastes are not clearly distinguished in the table. In addition, The EMU waste requirement and the brine solution requirement from the water processor should also be included as part of the solid waste per Reference 3.

As part of the FY2000 trade study activities, the inedible plant biomass waste data of the model were increased by ten times to include moisture content, assuming the water content of inedible plant biomass was 90 percent. The updated waste model was documented in the interim report for FY 2000 (Ref. 2).

In October 2000, recipe masses for diets using Advanced Life Support (ALS) Crops and Resupplied Foods were received from the JSC Food Group (Ref. 4). These recipe mass data have been listed in Table 2. These data, together with crop information acquired from the United State Department of Agriculture, which has been summarized in Table 3, form a reliable database in estimating the inedible plant biomass. The waste model therefore has been modified, aiming to improve the estimates for inedible biomass and packaging material, using these data. Other rates of the solid waste model including dry human waste, trash, paper, tapes, filters and miscellaneous remain unchanged.

3.0 APPROACH

The main goal of this model modification is to better estimate the inedible plant biomass and packaging material rates. The water contents in wastes for trash, packaging material and paper are estimated. Waste rates for EMU waste and brine solution from the water processor are also included.

The model has been modified for the following scenarios/missions (Ref. 3):

Scenario 0: Bio-Plex 120 Day Test, Lettuce and Potato Grown
Scenario 1: Transit Mission, Mostly Packaged Food
Scenario 2: Independent Exploration, Salad Crops Grown
Scenario 3: Exploration Mission, Low Carbohydrate Diet
Scenario 4: Extended Base, All Plant Crops Menu
Scenario 5: Extended Base, All Plant Crops Menu, Mostly Grown Food

Scenario 0 is added to the list to provide data for the proposed Bio-Plex 120 day test which is scheduled for 2005. Notice that the crew size for 120 day Bio-Plex test is four.

The procedures employed in the estimates for these scenarios are documented below:

Packaging Material:

1. The energy content of each diet has been calculated using recipe mass data from Table 2 and the crop composition data from Table 3. The energy content for a unit mass of protein, carbohydrate and fat used in the calculation is 16747, 16747 and 37680 kJ/kg (4.0, 4.0, 9.0 kcal/g), respectively.
2. From the energy content of each diet, the packaged food requirements to achieve the 11.82 MJ/person/day caloric requirements (Table 4.3.3, Ref. 4) can be estimated. The results are summarized in Tables 4 to 7 for scenarios 0, 2, 3 and 4.
3. The scenario 1, transit mission, is the mission in which the crew depends mostly on packaged food and uses minimum fresh food from salad crops. The grown food for this scenario is assumed as 50% of scenario 2 (independent exploration mission with salad machine). The fresh weight of packaged food is estimated as 1.5 kg/person/day, using the re-supply food energy of 7820 kJ/kg as estimated in Table 5 for scenario 2, in order to maintain the 11.82 MJ/person/day caloric requirement.
4. The packaging material rate for scenario 1 has been kept as 7.908 kg/6 person/day (1.318 kg/person/day) per Table 1 from the WPRR workshop. Scenario 1 has the highest packaging material rate because it has the maximum packaged food usage rate amongst all scenarios.
5. The packaging material rate for other missions can be obtained by scaling down from that rate of scenario 1. The rate is calculated by taking the ratio of packaging material rate to packaged food requirement for scenario 1, then multiplying this ratio by the packaged food requirement for each scenario.

Plant Biomass Waste:

1. The inedible plant biomass rate for each diet has been estimated with the recipe mass data from Table 2, the harvest index data as well as the water fraction data for both edible and inedible plant biomasses from Table 3. For crops where the water content of inedible biomass is unavailable, a water fraction of 0.9 is assumed. The results of the estimates for scenarios 2, 3 and 4 are summarized in Tables 8 to 10.
2. The edible biomass processing waste is estimated as 10%, 5%, 5%, 20%, 30% and 30% of the food grown for scenario 0, 1, 2, 3, 4 and 5 respectively. The 5% processing waste is selected for scenarios 1 and 2 in which the salad crops diet is used. The relatively high processing waste is assumed for scenarios 4 and 5 due to the presence of high percentage (23%) of soybean in the all ALS crops diet. The processing waste for the soybean is significant to produce products such as tofu and soybean milk.
3. A 10% table food waste from edible biomass is assumed for all scenarios.
4. The plant biomass waste is the total of inedible plant biomass plus the edible food waste from food processing and table food waste.

Both scenarios 4 and 5 are using the same crop menu (All Plant Crop Menu). For scenario 5, the grown food rate is selected as 150% of grown food of scenario 4. The packaged food requirement has been reduced to 0.166 kg/person/day to compensate the increase of grown food in order to maintain the 11.82 MJ/person/day caloric requirement. The 150% factor is selected so that the grown food is above 90 percent of the total food requirement for scenario 5. Once the grown food and packaged food requirements are determined, the packaging material and plant biomass waste rates can be estimated using the same procedure as described above.

Water Contents in Solid Wastes:

1. The water content for packaging material has been estimated using data from Shuttle Training Menu as part of the food system trade study (Ref. 5). The estimated water content in packaging material is approximately 20.5%.
2. Some measurements of water contents for paper towels and facial tissues were made in January 2001. The water absorption capacities for paper towels and facial tissues are 88% and 86 % by weight, respectively. The water contents for squeezed paper towels and facial tissues are 77% and 79% by weight. A 70% moisture content is assumed for towel/facial tissues in this study.
3. The measurement of water content for regular printer paper was also obtained. The water content for single-side and double-side wetted paper is 31% and 55% respectively. A 40% water content for wet paper is assumed.
4. Water content in wet trash has been estimated as 42%. The wet trash is mainly paper with some clothes/towels and pads/Tampons.

Other Solid Waste Requirements:

1. The EVA waste is estimated as 0.173 kg/crew/EVA for EMU diaper (Ref. 6) and 0.55 kg/crew/EVA of urine. This waste is only applicable for scenarios 2, 3, 4 and 5. A daily rate of 0.346 kg/day for diapers and 1.1 kg/day for urine is assumed since each EVA activity requires two crewmembers.
2. A water balance was performed for the Mars missions. It was assumed 97% of the total 27.58 kg/person/day water can be recovered by the water processor. The remaining 3% of water, including solids from urine, hand wash, shower and sweat etc. (total solids 0.098 kg/person/day), is collected as brine solution from the water processor and forwarded to the solid waste system. An overall of 11.84% of solids is estimated and used to determine brine solution rates.
3. A 0.023 kg/person/day toilet paper usage rate has been moved from the trash to human waste category. It is combined with the 0.03 kg/person/day dry feces rate to produce a total dry waste of 0.053 kg/person/day for feces and toilet paper category. The rate for this new category for 6 crewmembers is 0.318 kg/day as reported in the model summary.

4. RESULTS

The results of the modified solid waste model are summarized in Tables 11A to 11F. These tables have been prepared to cover one scenario per table. The significant improvement of these tables is to rearrange solid wastes into four main categories: wet human waste, wet plant biomass, wet trash and dry trash. For wet solid wastes, the water content and dry waste weight are listed in separate columns and the wet waste column is the summation of dry waste and water content columns. In addition, the water percentage for each waste component has been included in the summary. The result of calculated weight percentage for grown food is also included.

It has been noticed that the plant biomass wastes for scenarios 1 and 2 have been greatly reduced from the corresponding WPRR workshop values due to the low rate of ALS salad crops diet. The plant biomass wastes for scenario 3, 4 and 5 are much higher due to the inclusion of moisture content and edible plant biomass. The name ‘inedible plant biomass’ used in Table 1 has been replaced by ‘plant biomass waste’ in Tables 11A to 11F to reflect the fact that this item includes the inedible plant biomass and the edible food waste from food processing and table food waste. The new name properly describes the nature of the waste.

It should be mentioned that the results have been derived from today’s best data. The model should be updated should any better data become available in the future. This effort produces the revision A of the model.

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4. Alan Drysdal and Anthony Hanford, Advanced Life Support Systems Modeling and Analysis Project, Baseline Values and Assumptions Document (BVAD), JSC 39317, Document in Revision, Draft Date : October 2000.
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Table 1 - Solid Waste Model from WPRR Workshop - Units are kg/day (based on 6 person crew)

Waste Component	Transit, All Packaged Food	Independent Exploration, salad crops grown	Exploration Mission, Low carbohydrate diet	Extended Base, All plants menu	Extended Base, All plants menu
Dry Human Waste	0.720	0.720	0.720	0.720	0.720
Inedible Plant Biomass (1)	1.691	2.247	5.450	7.503	13.820
Trash	0.556	0.556	0.556	0.556	0.556
Packaging Material (2)	7.908	4.721	2.017	1.493	0.408
Paper	1.164	1.164	1.164	1.164	1.164
Tape	0.246	0.246	0.246	0.246	0.246
Filters	0.326	0.326	0.326	0.326	0.326
Miscellaneous	0.069	0.069	0.069	0.069	0.069
Total	**12.68**	**10.05**	**10.55**	**12.08**	**17.31**
Grown food	1.860	5.580	18.600	20.700	39.120
Packaged food	11.760	7.020	3.000	2.220	0.606
Mission Duration	180 days	600 days	600 days	10 years	10 years
Grown food (%) (3)	0	10	26	45	85
Packaged food (%)	100	90	74	55	15

ISS data is calculated to 3.3 Kg/day-person, based on 113 days between 5A and 6A with total trash generated of 737.5 KG for 2 crew.
Reference:ISS TRASH OPERATIONS PLAN, 11/4/99, Rodney Brown/JSC

Notes:

(1) Inedible plant biomass is calculated from the BVAD diet Inedible biomass/Average consumption

(2) Packaging material was calculated by taking the ratio of packaging material to packaged food for

(2a) The packaging material in the "All crop model" is assumed to be for an all packaged diet.
(The transit mission was assumed to represent the "All crop" waste model)

(3) The grown/packaged food ratio was interpolated based on the BVAD carbohydrate, all crop and 100% packaged food diets.

Table 2 - Recipe Masses for Diets Using Advanced Life Support Crops and Resupplied Foods

	Average Production Based on Consumption, Wet Mass [kg/person/day]		
Crop	Diet Using Only ALS Salad Crops[1]	Diet Using Salad and Carbohydrate Crops[2]	Diet Using All ALS Crops[3]
Soybean	n/a	n/a	0.234
Wheat	n/a	0.22	0.0963
White Potato	n/a	0.17	0.1047
Sweet Potato	n/a	0.18	0.0768
Rice	n/a	n/a	0.0214
Peanut	n/a	n/a	0.0288
Tomato	0.046	0.21	0.2854
Carrot	0.0365	0.04	0.0401
Cabbage	0.0194	0.0025	n/a
Lettuce	0.0156	0.021	0.0075
Dry Bean	n/a	0.013	0.0214
Radish	0.009	n/a	0.015
Celery	n/a	0.0075	n/a
Green Onion	0.0045	0.034	0.0226
Strawberry	n/a	n/a	n/a
Peppers	n/a	0.031	n/a
Pea	n/a	0.0038	n/a
Mushroom	n/a	0.0013	n/a
Snap Bean	n/a	0.01	n/a
Spinach	0.0048	0.04	0.0463
Crop Sub Total	0.1358	0.9841	1.0003
Water[4]	1.1581	2.1	0.6053
Resupplied Food Stuffs	1.168	0.5	0.0944
Resupplied Ambient Food	0.96	n/a	n/a
Resupplied Frozen Food	0.208	n/a	n/a
Total	2.4619	3.5841	1.7
Food Processing Waste	n/a	n/a	0.094

1. From Hall, Vodovotz, and Peterson (2000), Reference 4, BVAD Table 4.3.5. This diet assumes a 10-day cycle.
2. From Hall and Peterson (1999), Reference 4, BVAD Table 4.3.5. This diet assumes a 20-day cycle.
3. From Ruminsky and Hentges(2000), Reference 4, BVAD Table 4.3.5. This diet assumes a 10-day cycle.
4. Water for hydration, cooking and food preparation only.

Table 3 - Summary of Crop Data

Crop	Harvest Index		Edible BioMass, %						Inedible Biomass, %	Crop Variety
	BVAD	WPRR	Water	Fat	Carbo-hydrade	Protein	Ash	Total	Water	
Soybean	0.4	0.37	8.54	19.94	30.16	36.49	4.87	100		Glycine Max
Wheat	0.4	0.4	13	1.54	71.18	12.6	1.57	99.89		Triticum Aestivum L.
White Potato	0.7	0.7	78.96	0.1	17.98	2.07	0.89	100		Solanum Tuberosum
Sweet Potato	0.82	0.7	72.84	0.3	24.28	1.65	0.95	100.02	87.96	Ipomoea Batatas
Rice	0.4	0.4	10.37	2.92	77.24	7.94	1.53	100		Oryza Sativa L.
Peanut	0.27	0.27	6.5	49.24	16.14	25.8	2.33	100.01		Arachis Hypogaea
Tomato	0.48	0.48	93.76	0.33	4.64	0.85	0.42	100	92	Lycopersicon Esculentum
Carrot	0.9	0.9	87.79	0.19	10.14	1.03	0.87	100.02	87.79	Daucus Carota
Cabbage	0.9	0.9	92.15	0.27	5.43	1.44	0.71	100	92.15	Brassica Oleracea
Lettuce	0.95	0.95	95.58	0.22	2.32	1.29	0.59	100	95	Lactuca Sativa
Dry Bean		0.37	10.95	1.13	63.41	20.88	3.63	100		Phaseolus Vulgaris
Radish			94.84	0.54	3.59	0.6	0.54	100.11		Raphanus Sativus
Celery		0.7	94.64	0.14	3.65	0.75	0.82	100		Apium Graveolens
Green Onion		0.5	89.68	0.16	8.63	1.16	0.37	100		Allium Cepa
Strawberry		0.4	80.66	0.6	17.36	0.58	0.8	100		Psidium Cattleianum
Peppers		0.4	92.19	0.19	6.43	0.89	0.3	100		Capsicum Annuum
Pea		0.37	78.86	0.4	14.46	5.42	0.87	100.01		Pisum Sativum
Mushroom		0.5	91.83	0.33	4.08	2.9	0.9	100.04		Agarius Bisporus
Snap Bean		0.37	90.27	0.12	7.14	1.82	0.66	100.01		Phaseolus Vulgaris
Spinach		0.8	91.58	0.35	3.5	2.86	1.72	100.01		Spinacia Oleracea

1. The composition data including water content, fat, protein, carbohydrate and ash for each crop is acquired from the USDA Nutrient Data Base for Standard Reference. Notice that the relevent data for hydroponically grown crops may be different from the data above. Neverless, these data serve as a good starting point in estimating the inedible plant biomass.
2. The data for harvest index is collected from Table 3.11.1 of BVAD (JSC 39317, 1999) and WPRR Workshop (April 2000).

Table 4 - Calculation summary of packaged food requirement for Scenario 0 (Bio-Plex 120 Days Test, Lettuce and Potato Grown)

Crop	Growth Area	Crop Growth Rate	Dry edible grown per day	Wet edible grown per day	Harvest Index	Dry inedible grown per day	Moisture Content of Inedible	Wet inedible grown per day	Protein mass percent in wet edible	Fat mass percent in wet edible	Carbohydrate mass percent in wet edible	Protein energy per day	Fat energy per day	Carbohydrate energy per day	Total energy per day	Energy/person-d	Energy/person-d	Diet Energy % Satisfied by Crops
	m2	kg dry edible/m2-d	kg dry edible/d	kg wet edible/d	kg dry edible/kg dry total	kg dry/d	Water Mass %	kg wet /d	wet mass%	wet mass%	wet mass%	kCal/d	kCal/d	kCal/d	kCal/d	kCal/person-d	kJ/person-d	%
Lettuce	7.5	0.0058	0.044	0.87	0.95	0.002	0.950	0.046	1.3	0.2	2.3	44.71	17.16	80.41	142.27	23.71	99.21	0.839%
Potato	7.5	0.0195	0.146	0.74	0.7	0.063	0.850	0.418	2.1	0.1	15.3	62.82	7.37	455.20	525.38	87.56	366.37	3.100%
Totals	15		0.190	1.614		0.065		0.464								111.28	465.58	3.94%

Total Crop Energy (KJ/Person/Day)	465.6	From this calculation
Total Energy Including Resupply (KJ/Person/Day)	9500	Estimated from BVAD Table 4.3.6
Resupply Energy (KJ/Kg)	8400	Estimated from calculated resupply energy content
Packaged Food Requirement (Kg/Person/Day)	1.075527	
Adjusted Resupply to Match 11.82 MJ/Day Energy Value, (Kg/Person/Day)	1.351717	
Food from Crops (Kg/Person/Day)	0.269	From this calculation = 1.614/6
Total Food Item Including Packaging (Kg/Person/Day)	1.859301	
Food Packaging Material (Kg/Person/day)	0.238538	15% food packaging in food item, BVAD table 4.3.4 (Multiplyer is 0.15/0.85)

Table 5 - Calculation summary of packaged food requirement for Scenario 2 (Independent Exploration , ALS Salad Crops)

Crop	Wet edible grown per day	Protein mass percent in wet edible	Fat mass percent in wet edible	Carbohydrate mass percent in wet edible	Protein energy per day	Fat energy per day	Carbohydrate energy per day	Total energy per day	Energy/person-d	Diet Energy % Satisfied by Crops
	kg wet edible/person-d	wet mass%	wet mass%	wet mass%	kCal/person-d	kCal/person-d	kCal/person-d	kCal/person-d	kJ/person-d	%
Tomato	0.046	0.85	0.33	4.64	1.56	1.37	8.54	11.47	47.98	0.406%
Carrot	0.0365	1.03	0.19	10.14	1.50	0.62	14.80	16.93	70.84	0.599%
Cabbage	0.0194	1.44	0.27	5.43	1.12	0.47	4.21	5.80	24.28	0.205%
Lettuce	0.0156	1.29	0.22	2.32	0.80	0.31	1.45	2.56	10.72	0.091%
Radish	0.009	0.6	0.54	3.59	0.22	0.44	1.29	1.95	8.14	0.069%
Green Onion	0.0045	1.2	0.2	8.6	0.21	0.06	1.55	1.83	7.64	0.065%
Spinach	0.0048	2.9	0.4	3.5	0.55	0.15	0.67	1.37	5.74	0.049%
Totals	0.136								175.3	1.48%

Total Crop Energy (KJ/Person/Day)	175.3	From this calculation
Total Energy Including Resupply (KJ/Person/Day)	9310	Per BVAD Table 4.3.6
Packaged Food Requirement (Kg/Person/Day)	1.168	From Table 2
Resupply Energy (KJ/Kg)	7820.76332	
Adjusted Resupply to Match 11.82 MJ/Day Energy Value, (Kg/Person/Day)	1.48894054	
Food from Crops (Kg/Person/Day)	0.136	From this calculation
Total Food Item Including Packaging (Kg/Person/Day)	1.88749475	
Food Packaging Material (Kg/Person/day)	0.26275334	15% food packaing in food item, BVAD table 4.3.4 (Multiplyer is 0.15/0.85)

Table 6 - Calculation summary of packaged food requirement for Scenario 3 (Exploration Mission, Salad & Carbohydrate Crops)

Crop	Wet edible grown per day	Protein mass percent in wet edible	Fat mass percent in wet edible	Carbohydrate mass percent in wet edible	Protein energy per day	Fat energy per day	Carbohydrate energy per day	Total energy per day	Energy/person-d	Diet Energy % Satisfied by Crops
	kg wet edible/person-d	wet mass%	wet mass%	wet mass%	kCal/person-d	kCal/person-d	kCal/person-d	kCal/person-d	kJ/person-d	%
Wheat	0.22	12.60	1.54	71.18	110.88	30.49	626.38	767.76	3212.29	27.177%
W. Potato	0.17	2.07	0.10	17.98	14.08	1.53	122.26	137.87	576.85	4.880%
S. Potato	0.18	1.65	0.30	24.28	11.88	4.86	174.82	191.56	801.47	6.781%
Tomato	0.21	0.85	0.33	4.64	7.14	6.24	38.98	52.35	219.04	1.853%
Carrot	0.04	1.03	0.19	10.14	1.65	0.68	16.22	18.56	77.64	0.657%
Cabbage	0.0025	1.44	0.27	5.43	0.14	0.06	0.54	0.75	3.13	0.026%
Lettuce	0.021	1.29	0.22	2.32	1.08	0.42	1.95	3.45	14.43	0.122%
Dry Bean	0.013	20.88	1.13	63.41	10.86	1.32	32.97	45.15	188.92	1.598%
Radish	0	0.60	0.54	3.59	0.00	0.00	0.00	0.00	0.00	0.000%
Celery	0.0075	0.75	0.14	3.65	0.23	0.09	1.10	1.41	5.92	0.050%
Green Onion	0.034	1.16	0.16	8.63	1.58	0.49	11.74	13.80	57.76	0.489%
Pepper	0.031	0.89	0.19	6.43	1.10	0.53	7.97	9.61	40.20	0.340%
Pea	0.0038	5.42	0.40	14.46	0.82	0.14	2.20	3.16	13.22	0.112%
Mushroom	0.0013	2.90	0.33	4.08	0.15	0.04	0.21	0.40	1.68	0.014%
Snap Bean	0.01	1.82	0.12	7.14	0.73	0.11	2.86	3.69	15.45	0.131%
Spinach	0.04	2.86	0.35	3.50	4.58	1.26	5.60	11.44	47.85	0.405%
Totals	0.984								5275.8	44.63%

Total Crop Energy (KJ/Person/Day)	5275.8	From this calculation
Total Energy Including Resupply (KJ/Person/Day)	9740	Per BVAD Table 4.3.6
Packaged Food Requirement (Kg/Person/Day)	0.5	From Table 2
Resupply Energy (KJ/Kg)	8928.35377	
Adjusted Resupply to Match 11.82 MJ/Day Energy Value, (Kg/Person/Day)	0.73296568	
Food from Crops (Kg/Person/Day)	0.984	From this calculation
Total Food Item Including Packaging (Kg/Person/Day)	1.84641256	
Food Packaging Material (Kg/Person/day)	0.12934645	15% food packaing in food item, E (Multiplyer is 0.15/0.85)

Table 7 - Calculation summary of packaged food requirement for Scenario 4 (Extended Base, All ALS Crops)

Crop	Wet edible grown per day	Protein mass percent in wet edible	Fat mass percent in wet edible	Carbohydrate mass percent in wet edible	Protein energy per day	Fat energy per day	Carbohydrate energy per day	Total energy per day	Energy/person-d	Diet Energy % Satisfied by Crops	Fraction of Crops used in the Energy Calculation
	kg wet edible/person-d	wet mass%	wet mass%	wet mass%	kCal/person-d	kCal/person-d	kCal/person-d	kCal/person-d	kJ/person-d	%	
Soybean	0.234	36.49	19.94	30.16	341.55	419.94	282.30	1043.78	2953.62	24.988%	0.6763236
Wheat	0.0963	12.60	1.54	71.18	48.54	13.35	274.19	336.07	1406.11	11.896%	
W. Potato	0.1047	2.07	0.10	17.98	8.67	0.94	75.30	84.91	355.27	3.006%	
S. Potato	0.0768	1.65	0.30	24.28	5.07	2.07	74.59	81.73	341.96	2.893%	
Rice	0.0214	7.94	2.92	77.24	6.80	5.62	66.12	78.54	328.60	2.780%	
Peanut	0.0288	25.80	49.24	16.14	29.72	127.63	18.59	175.94	736.15	6.228%	
Tomato	0.2854	0.85	0.33	4.64	9.70	8.48	52.97	71.15	297.69	2.519%	
Carrot	0.0401	1.03	0.19	10.14	1.65	0.69	16.26	18.60	77.83	0.658%	
Cabbage	0	1.44	0.27	5.43	0.00	0.00	0.00	0.00	0.00	0.000%	
Lettuce	0.0075	1.29	0.22	2.32	0.39	0.15	0.70	1.23	5.15	0.044%	
Dry Bean	0.0214	20.88	1.13	63.41	17.87	2.18	54.28	74.33	310.99	2.631%	
Radish	0.015	0.60	0.54	3.59	0.36	0.73	2.15	3.24	13.57	0.115%	
Celery	0	0.75	0.14	3.65	0.00	0.00	0.00	0.00	0.00	0.000%	
Green Onion	0.0226	1.16	0.16	8.63	1.05	0.33	7.80	9.18	38.39	0.325%	
Pepper	0	0.89	0.19	6.43	0.00	0.00	0.00	0.00	0.00	0.000%	
Pea	0	5.42	0.40	14.46	0.00	0.00	0.00	0.00	0.00	0.000%	
Mushroom	0	2.90	0.33	4.08	0.00	0.00	0.00	0.00	0.00	0.000%	
Snap Bean	0.00	1.82	0.12	7.14	0.00	0.00	0.00	0.00	0.00	0.000%	
Spinach	0.05	2.86	0.35	3.50	5.30	1.46	6.48	13.24	55.38	0.469%	
Totals	1.000								6920.7	58.55%	

Total Crop Energy (KJ/Person/Day)	6920.7	From this calculation
Total Energy Including Resupply (KJ/Person/Day)	7740	From BVAD Table 4.3.6
Packaged Food Requirement (Kg/Person/Day)	0.0944	From Table 2
Resupply Energy (KJ/Kg)	8678.76135	
Adjusted Resupply to Match 11.82 MJ/Day Energy Value, (Kg/Person/Day)	0.56451317	
Food from Crops (Kg/Person/Day)	1.000	From this calculation
Total Food Item Including Packaging (Kg/Person/Day)	1.66443314	
Food Packaging Material (Kg/Person/day)	0.09961964	15% food packaing in food item, BVAD table 4.3.4 (Multiplyer is 0.15/0.85)

Table 8 - Inedible Biomass Calculation - Scenario 2 (Independent Exploration Mission/Salad Crops)

Based on 10-day cycle diet using ALS Salad Crops (Table 2)

Crop	Average Consumption kg/person-day, Wet	Harvest Index Dry Basis	Edible Biomass Water Fraction	Inedible Biomass Water Fraction	Inedible Biomass[1 & 2] kg/person-day
Soybean	0	0.37	0.675	0.9	0
Wheat	0	0.4	0.74	0.92	0
White Potato	0	0.7	0.79	0.9	0
Sweet Potato	0	0.7	0.73	0.88	0
Rice	0	0.4	0.74	0.9	0
Peanut	0	0.27	0.8	0.9	0
Tomato	0.046	0.48	0.94	0.92	0.037375
Carrot	0.0365	0.9	0.88	0.88	0.004056
Cabbage	0.0194	0.9	0.92	0.92	0.002156
Lettuce	0.0156	0.95	0.96	0.95	0.000657
Dry Bean	0	0.37	0.8	0.9	0
Radish	0.009	0.9	0.95	0.9	0.0005
Celery	0	0.7	0.95	0.9	0
Green Onion	0.0045	0.5	0.9	0.9	0.0045
Strawberry	0	0.4	0.81	0.9	0
Peppers	0	0.4	0.92	0.9	0
Pea	0	0.37	0.79	0.9	0
Mushroom	0	0.5	0.92	0.9	0
Snap Bean	0	0.37	0.9	0.9	0
Spinach	0.0048	0.8	0.92	0.9	0.00096
Crop Sub Total	0.1358				0.050203
Water	1.1581				
Total	1.2939				
Resupplied Food Stuffs[3]	1.489				
Total	2.7829				

1. Inedible Biomass = Edible Biomass*(1-Edible Biomass Water Fraction)/(1-Inedible Biomass Water Fraction)
* (1 - Harvest Index) / Harvest Index.
2. The inedible biomass is calculated based on the average crop consumption requirement per Table 2.
The calculated value does not include inedible biomass rate due to crop requirement for food processing and table food wastes.

3. The resupplied food requirement is taked from the scaled-up value calculated in Table 5 for this scenario.

Table 9 - Inedible Biomass Calculation - Scenario 3 (Exploration Mission/Low Carbohydrate Diet)

Based on 20-day cycle diet using Salad and Carbohydrate Crops (Table 2)

Crop	Average Consumption kg/person-day, Wet	Harvest Index Dry Basis	Edible Biomass Water Fraction	Inedible Biomass Water Fraction	Inedible Biomass[1 & 2] kg/person-day
Soybean	0	0.37	0.675	0.9	0
Wheat	0.22	0.4	0.74	0.92	1.0725
White Potato	0.17	0.7	0.79	0.9	0.153
Sweet Potato	0.18	0.7	0.73	0.88	0.173571
Rice	0	0.4	0.74	0.9	0
Peanut	0	0.27	0.8	0.9	0
Tomato	0.21	0.48	0.94	0.92	0.170625
Carrot	0.04	0.9	0.88	0.88	0.004444
Cabbage	0.0025	0.9	0.92	0.92	0.000278
Lettuce	0.021	0.95	0.96	0.95	0.000884
Dry Bean	0.013	0.37	0.8	0.9	0.04427
Radish	0	0.9	0.95	0.9	0
Celery	0.0075	0.7	0.95	0.9	0.001607
Green Onion	0.034	0.5	0.9	0.9	0.034
Strawberry	0	0.4	0.81	0.9	0
Peppers	0.031	0.4	0.92	0.9	0.0372
Pea	0.0038	0.37	0.79	0.9	0.013588
Mushroom	0.0013	0.5	0.92	0.9	0.00104
Snap Bean	0.01	0.37	0.9	0.9	0.017027
Spinach	0.04	0.8	0.92	0.9	0.008
Crop Sub Total	0.9841				1.732035
Water	2.1				
Total	3.0841				
Resupplied Food Stuffs[3]	0.733				
Total	3.8171				

1. Inedible Biomass = Edible Biomass*(1-Edible Biomass Water Fraction)/(1-Inedible Biomass Water Fraction)
* (1 - Harvest Index) / Harvest Index.

2. The inedible biomass is calculated based on the average crop consumption requirement per Table 2.
The calculated value does not include inedible biomass rate due to crop requirement for food processing and table food wastes.

3. The resupplied food requirement is taked from the scaled-up value calculated in Table 6 for this scenario.

Table 10 - Inedible Biomass Calculation - Scenario 4 (Extended Base Mission/All Plant Crops Menu)

Based on 10-day cycle diet using all ALS Crops (Table 2)

Crop	Average Consumption kg/person-day, Wet	Harvest Index Dry Basis	Edible Biomass Water Fraction	Inedible Biomass Water Fraction	Inedible Biomass[1 & 2] kg/person-day
Soybean	0.234	0.37	0.675	0.9	1.294905
Wheat	0.0963	0.4	0.74	0.92	0.469463
White Potato	0.1047	0.7	0.79	0.9	0.09423
Sweet Potato	0.0768	0.7	0.73	0.88	0.074057
Rice	0.0214	0.4	0.74	0.9	0.08346
Peanut	0.0288	0.27	0.8	0.9	0.155733
Tomato	0.2854	0.48	0.94	0.92	0.231888
Carrot	0.0401	0.9	0.88	0.88	0.004456
Cabbage	0	0.9	0.92	0.92	0
Lettuce	0.0075	0.95	0.96	0.95	0.000316
Dry Bean	0.0214	0.37	0.8	0.9	0.072876
Radish	0.015	0.9	0.95	0.9	0.000833
Celery	0	0.7	0.95	0.9	0
Green Onion	0.0226	0.5	0.9	0.9	0.0226
Strawberry	0	0.4	0.81	0.9	0
Peppers	0	0.4	0.92	0.9	0
Pea	0	0.37	0.79	0.9	0
Mushroom	0	0.5	0.92	0.9	0
Snap Bean	0	0.37	0.9	0.9	0
Spinach	0.0463	0.8	0.92	0.9	0.00926
Crop Sub Total	1.0003				2.514076
Water	0.6053				
Total	1.6056				
Resupplied Food Stuffs[3]	0.5645				
Total	2.1701				

1. Inedible Biomass = Edible Biomass*(1-Edible Biomass Water Fraction)/(1-Inedible Biomass Water Fraction)
* (1 - Harvest Index) / Harvest Index.

2. The inedible biomass is calculated based on the average crop consumption requirement per Table 2.
The calculated value does not include inedible biomass rate due to crop requirement for food processing and table food wastes.

3. The resupplied food requirement is taked from the scaled-up value calculated in Table 7 for this scenario.

Table 11 - Solid Waste Model - Units are Kg/day (based on 6 person crew) - Revision A

Scenario		Bio-Plex, Lettuce & Potato 0	Transit, All Packaged Food 1	Independent Exploration, salad crops grown 2	Exploration Mission, Low carbohydrate diet 3	Extended Base, All plants menu 4	Extended Base, All plants menu 5
Waste Component							
Wet Human Waste							
Feces & Toilet Paper		0.858	0.858	0.858	0.858	0.858	0.858
Brine for Urine		3.048	3.048	3.048	3.048	3.048	3.048
Brine for Shower/Handwash/Sweat		1.524	1.524	1.524	1.524	1.524	1.524
EMU Waste		0.000	0.000	1.446	1.446	1.446	1.446
Wet Plant Biomass		0.900	0.237	0.474	15.607	24.150	36.225
Wet Trash		0.418	0.418	0.418	0.418	0.418	0.418
Trash(Paper)							
Packaging Material		7.126	7.908	7.850	3.864	2.976	0.878
Wipes/Tissues		1.164	1.164	1.164	1.164	1.164	1.164
Dry Trash							
Tape		0.246	0.246	0.246	0.246	0.246	0.246
Filters		0.326	0.326	0.326	0.326	0.326	0.326
Miscellaneous		0.069	0.069	0.069	0.069	0.069	0.069
	Total	**15.68**	**15.80**	**17.42**	**28.57**	**36.23**	**46.20**
Grown food		1.614	0.407	0.815	5.905	6.000	9.000
Packaged food		8.110	9.000	8.934	4.398	3.387	1.000
% food Grown		16.598	4.331	8.358	57.312	63.918	90.004
Mission Duration		120 days	180 days	600 days	600 days	10 years	10 years